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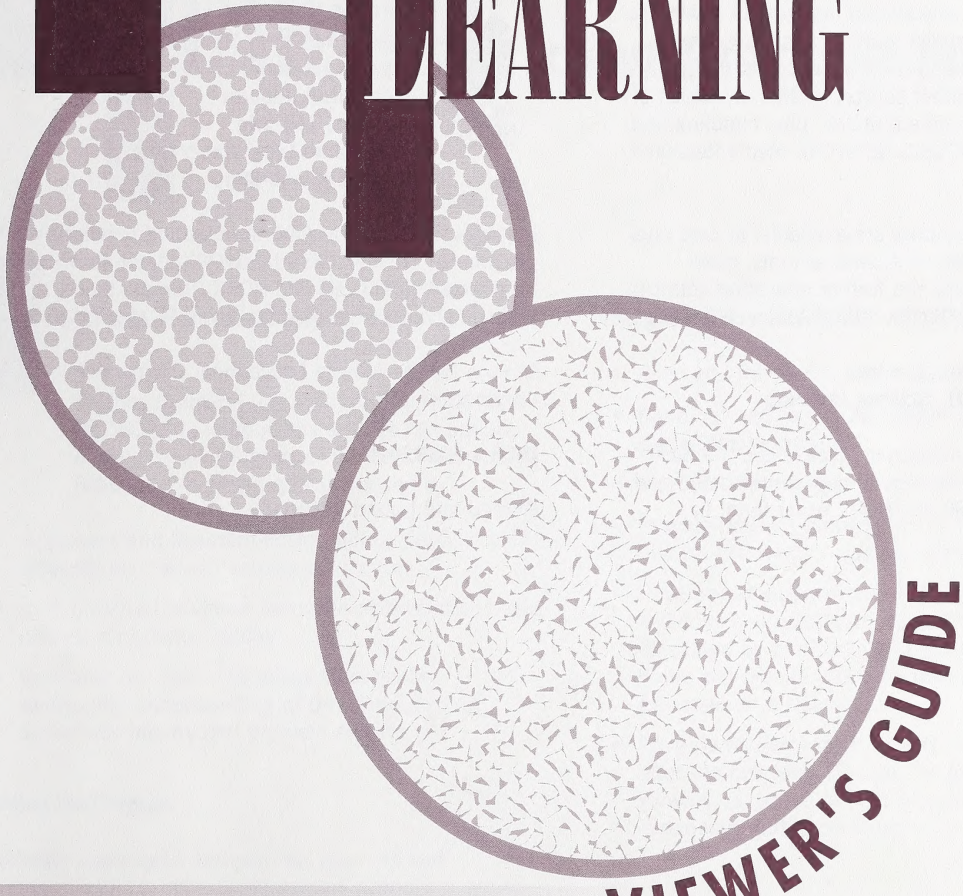
SCIENCE LEARNING



VIEWER'S GUIDE

ACCESS NETWORK

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SCIENCE LEARNING

COMING TO KNOW THE WORLD

Program Description

Science Learning was produced by ACCESS NETWORK to support the science component of the Alberta Program of Studies: Elementary Schools. The purpose of this video is:

- to present and illustrate some findings from recent research on student learning in science
- to familiarize the viewer with one of several possible models for science inquiry
- to enable the viewer to assist students in developing understanding of the world through systematic inquiry and problem solving.

Using the Program

Science Learning is designed for teachers and administrators in Alberta elementary schools to assist with implementation of the Elementary Science Program of Studies. It can be used for individual viewing or at inservices, professional development days or staff meetings.

Suggested Inservice Outline

- Read and follow the pre-viewing suggestions.
- Hand out and follow the viewer guidelines and discussion questions.
- View the tape: length 30 minutes.
- Provide time for participants to complete and discuss the viewing questions and activities.
- Have participants complete the post-viewing activities and questions independently. Some will be discussed by participants in groups immediately. Some will require attention over time and can be discussed at a later date.
- Have participants meet, briefly, one week (or longer) after the inservice. Discuss the remaining post-viewing questions in light of subsequent classroom experience and application.

Pre-viewing Suggestions

1. Read, reflect upon, and respond to the following questions. Write your answers on an index card, and set the card aside until you have viewed the tape and are considering the post-viewing suggestions.

- What is knowledge?
- How do individuals learn?
- What is science?
- What is science education?

2. Complete individually, or in groups, the following chart reflecting your personal beliefs. Share your ideas with other individuals or groups.

Goals of Science Teaching

Goals of Science Learning

3. The following conversation arose spontaneously as students discussed a friend's birthday. The children's comments provide insight into their understanding of the relationship between age, body size and growth.

Linda: *Today's Mandy's birthday!!*

Teacher: *Well, Happy Birthday Mandy. How does it feel to be one year older?*

Mandy: *Great! I feel older, and bigger, and taller even.*

Teacher: *Do you mean taller since yesterday?*

Mandy: *Yes.*

Teacher: *Why is that?*

Mandy: *Because I'm six.*

Ross: *Yesterday she was five. She is taller today.*

Linda: *On that very day when it's your birthday you're bigger. If I was four and on one day I got to be five, I'd be much bigger.*

Consider individually, or in groups, how you as a classroom teacher might respond to this exchange of ideas.

4. Recall significant science experiences in your past and share them in groups, if possible. Focus on what caused the experiences to be signifcant for you, and on why they remain clear memories today.

5. Obtain a copy of the current science component of the Program of Studies: Elementary Schools. Read the Rationale and Philosophy, General Learner Expectation, and Specific Learner Expectations.

   Answer, either individually or in groups, the following questions:

   - What is the focus of the Elementary Science Program of Studies?
   - What is inquiry?
   - What does recent research literature in science education tell us about how children come to understand science concepts?

6. Review the Viewer Guidelines and Discussion Questions before the program. This will help you to focus on specific aspects of the program in preparation for discussion.

Viewer Guidelines and Discussion Questions

The following information, activities and questions may be read before the program and completed during viewing.

Introduction

> *Science is not a mechanism but a human progress, and not a set of findings but a search for them.* (Bronowski, 1965, p. 63)

Children are engaged in a search for understanding of their world. They look for order and predictability around them as a basis for personal action. This intuitive inquiry can be a random and inefficient process. Science experiences in the elementary school will provide for the development of skills which allow children to become more effective in their search for understanding and more systematic in their inquiry. At the same time, science studies will take into consideration the prior ideas children bring to new experiences, seek to challenge and further develop these ideas, and assist students in the active construction of new meaning.

1. Briefly outline the two main objectives of the Elementary Science Program of Studies as presented in this section of the program.
2. Dr. Gustafson discusses two important findings from recent research in science education. What are they?
3. What is "children's science"?
   What is "scientist's science"?
   How are they different?
4. Describe what you see in the students' faces, actions and/or manner as they pursue their science inquiry.
5. In the introductory section of the video program, a teacher mentions that science is something happening around us all the time, that we can all explore, construct and communicate understanding in science.

   Re-organize the component skills of the inquiry process (e.g., questioning, observing) under the following headings:

Explore	Construct	Communicate

6. As you view the program, consider what the teacher and students are doing during each stage of inquiry. How might each stage contribute to the construction of meaning for children?

Stage of Inquiry	Teacher	Student	Construction of Meaning

The Starting Point for Inquiry (Questioning)

> *The formulation of a problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skill. To raise new questions, new possibilities, to regard old problems from a new angle, requires creative imagination and marks real advances in science.* (Albert Einstein)

Inquiry often begins with the identification of questions or problems of personal interest and relevance. These questions may arise from a student's own curiosity, from events and situations encountered formally or informally, from planned or unplanned observations or discrepant or unexplained events, from observation experiences prepared by a teacher in an instructional setting, or directly from the teacher in readily testable form. Questions and problems stimulate recall of prior ideas and experiences, and lead to a search for resolution and understanding.

1. What type of environment is necessary for students to feel comfortable expressing their questions and voicing problems which interest them? How might teachers foster this kind of environment?

2. In the program, classroom examples of questions or problems to spark inquiry are provided. Give two examples of these, as well as their sources (e.g., teacher, student, other).

3. A student shares the following question with the class: *How do plants grow?*

   How might you assist students to pursue this question through systematic inquiry, and to develop related conceptual understanding? Include suggestions for narrowing the broad question above into a form which may be investigated more easily.

Children's Ideas (Proposing Ideas, Designing Experiments)

> *The need to be right all the time is the biggest bar there is to new ideas. It is better to have enough ideas for some of them to be wrong than to be always right by having no ideas at all.*
> (Edward De Bono)

Children come to science experiences with prior ideas which they have used to understand and make sense of the world. These understandings, known as

"children's science", are often scientifically naive and contradictory to the established views of the scientific community. Five different patterns of "children's science" can be described. (Gilbert, Osborne and Fensham, 1982)

- Everyday Language

  A student may listen to, or read a statement in science and make sense of it by using the everyday interpretation of a word (the word "conservation", for example). This interpretation is not the one intended by the teacher or textbook writer. Thus familiarity with the everyday use of a word may not be an advantage in learning science. In any conflict between life/world meaning and defined scientific meaning, the one most frequently reinforced by social usage will overpower the other. This trap of familiarity can be avoided by those open to its existence, and the manner in which a problem or question is presented may act as a trigger for one type of knowledge rather than another. Students able to choose between scientific notions and everyday notions may be more successful in their science learning.

- Self-centered and Human-centered Viewpoint

  Students may interpret and consider things in terms of human experiences and commonly held values. Simple human concerns determine how phenomena are interpreted.

- Nonobservables Do Not Exist

  To some students, a physical quantity is not present in a given situation unless it, or its effects, can be observed.

- Endowing Objects with Characteristics of Humans and Animals

  Children may endow objects with feeling, will or purpose.

- Endowing Objects with a Certain Amount of a Physical Quantity

  Students may grant a physical quantity to objects, and give this quantity an unwarranted physical reality.

Knowing children's ideas about phenomena to be investigated is important for a number of reasons. It is most helpful in allowing teachers to assist students make connections between new and old understandings, and in the development of personal, relevant meaning.

Students will propose ideas based on their prior knowledge which may solve the initial problem or answer the initial question.

A prediction may take this form:

> When I *(do something)*,
> I think *(something will happen)*.
>
> e.g., When (or if) I *put a mealworm under strong light*, I think *it will move away.*
>
> If I *add more glycerin to my soap solution*, I think *it will give me larger bubbles.*

A hypothesis may take this form:

> When I *(do something, this happens)* because *(of this explanation)*.
>
> e.g., When I *put a mealworm under a bright light, it will move away* because *it gets too hot.*
>
> I think that *adding glycerin to the soap solution causes the bubbles to be bigger* because *the bubbles become stronger.*

Predictions and hypotheses will often lead students to devise a plan to gather data and to test their ideas.

1. How might you elicit the ideas children already hold in relation to a topic? The teachers in this program provide a variety of ways in which they make use of this knowledge.

2. One teacher expresses how children respond positively to interest in their prior knowledge. Of what benefit is this approach to the students themselves?

3. Give both the everyday understanding as well as the scientific understanding for the following terms: stable, energy, equilibrium, conservation.

4. Match the following student quotes with the pattern of "children's science" they best illustrate. (Gilbert, Osborne and Fensham, 1982)

   The heat makes the air bubble come out of the element.

   Ice is just frozen water. What's the difference between frozen water and ordinary water? *You can't drink it very good.*

   Oh, it has evaporated. What does that mean? *Well, it has not gone into the same steam form because it doesn't look as if it has gone up in the water state...it must have split up because you couldn't sort of see steam or anything rising.* What do you mean split up? *The hydrogen and oxygen molecules.*

   The air is made of small particles. Is there anything else made up of small particles? *Glass...they are made out of small particles of sand which have been turned hot...turned clear and then sort of take them out.*

   It's cold in there and the chill's coming to the outside...the coldness just um...oh, it's cold in there and it's just trying to get out... and it's somehow got out.

   The plunger sticks to the glass because of the power of suction.

   We can hear because sound bounces around and our ear sends out something to catch it.

   The heat makes the red liquid lighter and so it rises.

5. Choose a prediction or hypothesis expressed by a student in this section of the program. How might you respond to this idea, and assist the student in further inquiry?

Hands-on (Doing Experiments, Observing and Measuring)

> *There are, oddly, no technical rules for success in science....Independence and originality, dissent and freedom and tolerance, such are the first needs of science; and these are the values which, of itself, it demands and forms.*
> (Bronowski, 1965, p. 62)

Active involvement in hands-on science activities provides students with the opportunity to test their ideas and to construct new meaning through the evidence of their senses and with the assistance of social interaction. Students may use existing concepts to deal with new phenomena and observations (called assimilation). Often, however, current understandings aren't adequate for the student to grasp new knowledge fully. Then, he or she may be motivated to replace or re-organize his or her central concepts (called accommodation). (Posner, Strike, Hewson and Gertzog, 1982)

Whenever learners encounter new phenomena during science activities, they will rely on their current concepts to organize the investigation, to ask relevant questions, to propose ideas, to decide what to observe, and how to make sense of these observations. If a student is dissatisfied with the ability of existing concepts to solve problems or answer questions, then he or she may be ready to reject these concepts and to develop more scientific understanding of the phenomena being investigated. At this point, another student or the teacher may suggest a competing view for consideration and discussion. This view may be accepted if it appears intelligible, plausible, and fruitful (Posner, Strike, Hewson, and Gertzog, 1982).

Each hands-on activity provides the chance for new adjustments to existing concepts, and each new adjustment lays the groundwork for a re-organization or change in a student's central conceptual framework. Thus, repeated and frequent involvement in hands-on investigation and time for discussion and negotiation of ideas arising from this involvement is imperative for science learning to occur.

1. Why do the teachers featured in this program feel active involvement is so important in elementary science?

2. What might your role be during hands-on activities?

3. Science has sometimes been criticized as being "too noisy", "too chaotic", "too difficult to prepare for and organize", "too messy." Respond to these comments in light of the program and the discussion above.

4. Why is group and/or partner work encouraged in science?

5. List some possible sources of ideas for hands-on activities which may challenge children's existing ideas.

Processing Ideas

> *Science is not memory or magic, but rather a disciplined form of human curiosity.* (Sears and Kessen, 1964, p. 4)

Information, data and ideas gathered during science activities will be organized and presented in a variety of ways. Teachers assist students in choosing appropriate forms of recording, in sharing, and in recognizing patterns and trends.

1. List methods of data recording seen in this, and other, sections of the program.

2. Why is effective record keeping important to the construction of meaning and to the inquiry process?

3. How might you assist a student to recognize patterns and trends in classroom data collected during science inquiry?

The Construction of Meaning (Interpreting Data)

> *The Wu Li Master does not speak of gravity until the student stands in wonder at the flower petal falling to the ground. He does not speak of laws until the student, of his own, says, "How strange!"* (Zukav, 1979, p. 8)

Reflecting and talking about activities and results will promote the development of science concepts and will assist students in their progression from "children's science" to "scientist's science."

There are at least five patterns of outcomes from science instruction. (Gilbert, Osborne and Fensham, 1982)

- The Undisturbed "Children's Science" Outcome

- The Two Perspectives Outcome (a student may reject the "scientist's science" as an acceptable way to view the world, yet will consider it as something to be learned for tests, etc.)

- The Reinforced Outcome (the "children's science" viewpoint is maintained following teaching, with scientific concepts put forward to support a particular understanding)

- The Mixed Outcome (learner's views are a mixture of "children's science" and "scientist's science")

- The Unified Science Outcome (the learner obtains a coherent scientific understanding which relates directly to his or her environment)

The aim of science education is a unified science outcome. Yet, this outcome is not always realized. Students must first perceive dissatisfaction with existing concepts, and then encounter science ideas which are intelligible, plausible and fruitful to them. The more secure and confident individuals feel within the world, the more likely they will be to accept an explanation different than the one they believe to be true.

Teachers can talk to students in ways that will help them change their conceptions. They can focus on student explanations, prove responses, balance closed and open-ended discussions in order to bring out student ideas as well as to direct and explain scientific explanations. They can provide more time for students to experiment, think about, discuss, practise and apply new ideas. Teachers can also represent student ideas and inferences in a multitude of forms to stimulate the development of conceptual understanding. Teachers may choose to introduce the scientific explanation as one more idea or inference, taking care not to model "right answer" thinking, yet encouraging students to construct their own understanding.

1. Keeping in mind the development of science understanding, how might you respond to a student who claims his "experiment didn't work"?

2. Two teachers in this section of the program comment on the impact of science learning on the lives of their students. Briefly summarize what they say.

3. According to teachers in this program and to the discussion above, what might you do if students don't seem to be learning the science concepts you had planned to focus on?

4. A student's understanding of science concepts associated with a particular unit (e.g., light and colour, change) is still naive after numerous challenging hands-on experiences, i.e., his progress report indicates he is progressing satisfactorily in science. How might you explain this to colleagues, administrators and parents?

The Practice of Science Teaching

> ....*What science has to teach us is not its techniques but its spirit; the irresistible need to explore.* (Bronowski, 1965, p. 72)

1. Speculate about how the teachers featured in this program feel about science teaching.

2. The chart below highlights some teaching strategies that are helpful in assisting students to examine existing conceptions and construct new meaning from science activities. It may be used to determine which strategies are already part of your classroom practice, and which strategies you may choose to incorporate in the future.

3. What further steps will you take following this inservice in order to teach science by inquiry (using the processes of science to learn science) rather than to teach science by inquiry (focusing on just the processes of science themselves)?

Strategy	Present Practice	Future Practice
Seeking out and using student questions and ideas to guide lessons and units		
Accepting and encouraging student initiation of ideas		
Promoting student leadership, collaboration, location of information, and action-taking as a result of the learning process		
Using student thinking, experiences and interests to drive lessons (this may mean altering teaching plans)		
Encouraging the use of alternative sources for information, both from written materials and experts		
Using open-ended questions and encouraging students to elaborate on their questions and responses		
Encouraging students to suggest causes for events and situations, and encouraging them to predict consequences		

Encouraging students to test their own ideas		
Assisting students to focus on specific aspects of the learning experience		
Encouraging alternative modes of organization and representation of information and data		
Seeking out student ideas before presenting teacher ideas or before studying ideas from textbooks or other sources		
Encouraging students to challenge each other's conceptualizations and ideas		
Providing a wide range of potential connections between ideas and concepts		
Using cooperative learning strategies that emphasize collaboration, respect individuality, and use division of labour tactics		
Encouraging adequate time for reflection and analysis; respecting and using all ideas that students generate		
Encouraging self-analysis, collection of real evidence to support ideas, and reformulation of ideas in light of new experiences and evidence		
Encouraging students to accept responsibility for the development of their own science understanding.		

(Yager, 1989 and Osborne and Wittrock, 1983)

Science Learning: Coming to Know the World

Science at its highest level is ultimately the organization of, the systematic pursuit of, and the enjoyment of wonder, awe, and mystery. (Maslow, 1966, p. 151)

1. Compare and contrast the following approaches to elementary science. (Gustafson, 1993)

2. Why is wonder so important to science and science learning?

To conclude, I think that there is only one way to science—or to philosophy, for that matter: to meet a problem, to see its beauty and fall in love with it; to get married to it, and to live with it happily, till death do ye part—unless you should meet another and even more fascinating problem, or unless, indeed, you should obtain a solution. (Sir Karl Popper)

Conceptual Change Approach	Discovery Approach	Process Approach	Content Mastery Approach
Children learn best when opportunities are provided for them to construct and recognize knowledge while actively investigating the fundamental concepts and theories of science.	Children learn best by discovering things for themselves.	Children learn best by learning and practising the process of science.	Children learn best by being told answers by an authoritative source.

Post-viewing Suggestions

The following questions and activities can be addressed immediately after viewing the program, or can be reserved for consideration at a later date.

1. Discuss the viewing questions.

2. Teachers, too, have a wide variety of viewpoints about science, knowledge and learning. A teacher's view will interact with the science curriculum and its materials as he or she prepares for teaching. Curricular materials may or may not modify a teacher's viewpoint in the direction of "scientist's science." It is the interaction of "children's science" and their teacher's science that will have profound implications for the outcomes of science teaching.

   Review the responses written on index cards (see pre-viewing suggestions) in light of the above statement. Reflect on the initial questions, and on how your ideas may have changed as a result of viewing this program.

   It may also be appropriate to review and discuss responses to the other pre-viewing suggestions in light of the information presented during the inservice.

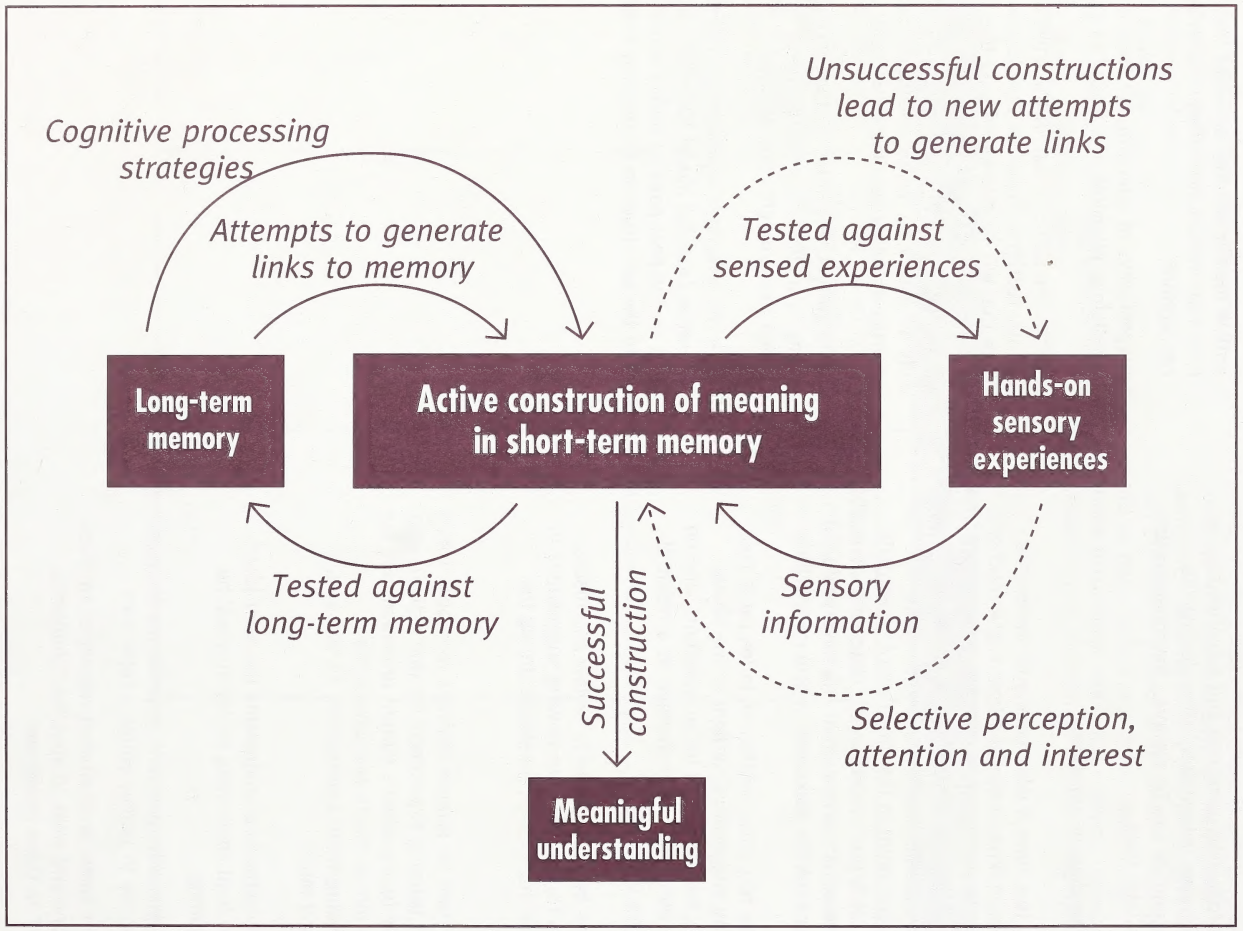
3. It is important for science teachers to choose topics and order learning experiences so that activities not only relate to a student's current understanding but also help him or her to restructure this understanding when appropriate. To this end, a science unit must:

   - suggest methods of addressing the prior ideas children hold concerning topics they will be investigating
   - outline possible questions or problems students may choose to pursue within a topic area
   - consider some likely student responses to these questions and ways to spot the "children's science" in these responses
   - provide teacher background in appropriate scientific ways to think about and explain questions
   - outline inquiry-oriented activities that may introduce dissatisfaction with students' existing conceptions
   - suggest ways of rendering the "scientist's science" intelligible, plausible and fruitful to students.

   Consider the grade or age of the children you are currently teaching. Focus on one science unit or theme that will be addressed over the next year. Using the points above, review and restructure the unit to allow children the opportunity to develop skills necessary for systematic inquiry and to construct an understanding of scientific concepts.

4. How might you engender in students the belief that coming to understand scientific ideas is dependent on their own thoughts and actions?

5. Relate the schematic representation of the Generative Learning Model (Osborne and Wittrock, 1983) on the next page to both a process of inquiry and to the construction of meaning in science.


Unsuccessful constructions lead to new attempts to generate links
Cognitive processing strategies
Attempts to generate links to memory
Tested against sensed experiences
Long-term memory
Active construction of meaning in short-term memory
Hands-on sensory experiences
Tested against long-term memory
Successful construction
Sensory information
Selective perception, attention and interest
Meaningful understanding

References

Bronowski, Jacob. *Science and Human Values*. New York: Harper and Row, 1965.

Einstein, Albert. *Ideas and Opinions*. New York: Teacher's College Press, 1974.

Gilbert, John K., Osborne, Roger J. and Fensham, Peter J. "Children's Science and Its Consequences for Teaching", *Science Education*, 1982, 66(4), pp. 623-633.

Gustafson, Dr. B. *Children Constructing Scientific Knowledge: Ideas from Research*. Unpublished paper, 1993.

Hausfather, Samuel J. "It's Time for a Conceptual Change", *Science and Children*, 1992, 30(3), pp. 22-23.

Hodson, Derek. "Toward a Philosophically More Valid Science Curriculum", *Science Education,* 1988, 721, pp. 19-40.

Maslow, Abraham. *The Psychology of Science: A Reconnaissance*. South Bend, Indiana: Gateway Editions, Ltd., 1966.

Osborne, R. J. "Learning Science: A Generative Process", *Science Education,* 1983, 67(4), pp. 489-508.

Pope, Maureen and Gilbert, John. "Personal Experience and the Construction of Knowledge in Science", *Science Education,* 1983, 67(2), pp. 193-203.

Posner, George J., Strike, Kenneth A., Hewson, Peter W. and Gertzog, William A. "Accommodation of a Scientific Conception: Toward a Theory of Conceptual Change", *Science Education,* 1982, 66(2), pp. 211-227.

Sears, Paul B. and Kessen, William. "Statement of Purposes and Objectives of Science Education in School", *Journal of Research in Science Teaching,* 1964, 2(1), pp.3-6.

Yager, Robert E. "The Constructivist Learning Model", *The Science Teacher,* 1991, September, pp. 52-57.

Zukav, Gary. *The Dancing Wu Li Masters: An Overview of the New Physics*. New York: Bantam Books, Inc., 1979.

Other Recommended Readings

Feyerabend, P.K. *Against Method*. London: New Left Books, 1975.

Goldberg, Jeff. *Anatomy of a Scientific Discovery*. New York: Bantam Books, 1988.

Hacking, Ian (ed.). *Scientific Revolutions*. Great Britain: Oxford University Press, 1981. (note: see papers by Kuhn, Lakatos, Popper, Hacking and Feyerabend)

Harlen, Wynne and Jelly, Sheila. *Developing Science in the Primary Classroom*. Essex: Oliver and Boyd Publishers, 1989.

Harlen, Wynne. *Teaching and Learning Science*. Paul Chapman Publishing Ltd., 1985.

Harlen, Wynne. *The Teaching of Science: Studies in Primary Education*. London: David Fulton, 1992.

Kuhn, T.S. *The Structure of Scientific Revolutions,* 2nd Edition. Chicago: University of Chicago Press, 1970.

Kelly, G.A. *The Psychology of Personal Constructs*. New York: W.W. Norton and Co., Inc., 1955. (note: see first two chapters)

Millar, Robin (ed.) *Doing Science: Images of Science in Science Education*. London: Falmer Press, 1989.

Osborne, Roger and Freyberg, Peter. *Learning in Science: The Implications of Children's Science*. Portsmouth, NH: Heinemann, 1985.

Watson, James P. *The Double Helix*. New York: Atheneum Publishers, 1968.

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